THE

AMERICAN METER CO.

Calorimetry

NEW YORK

PHILADELPHIA - CHICAGO

CALORIMETRY

ESTABLISHED 1834

The American Meter Co.

ELEVENTH AVE. and 47th ST.

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Peoples Gas Building

PHILADELPHIA
Arch and 22nd Sts.

1914

CONTENTS.

Calorimetry.

In the beginning the gas industry was devoted to illumination only and for many years every effort was made to improve the light giving qualities of gas and to devise the best burners which could be invented for bringing out those qualities.

The science of photometry was then developed to measure by comparison with an accepted standard the amount of light obtainable from a given quantity of the gas tested.

Later, gas being found useful for heating and cooking and for numerous industrial purposes, its thermal or heat producing quality became important. With the introduction of incandescent mantles for gas lighting, the heating value began to assume greater importance than the illuminating power and as, at present, 80% to 90% of the gas sold is used for its heat, the fairest test of its value to the majority of consumers is the determination of its heating quality.

This cannot be deduced from the results of photometric tests as there is no definite relationship between the light and the heat giving qualities, it being possible to change the composition of the gas materially, substituting one non-illuminant of high heating value for another giving much less heat without causing any decided change in the candle power. Therefore, the heat producing or calorific value must be sought by other means.

This is the science of calorimetry—the measurement of heat.

As in photometry, there is a unit of measurement or standard of comparison, this heat unit being called in countries where the metric system of weights and measures is in general use, a "Calorie," and where the English system prevails, as in this country, the British thermal unit, usually abbreviated to B. t. u.

The Calorie as a heat unit may be large or small: the large (Kg-calorie, written also, Calorie, with a capital C), representing the amount of heat necessary to raise the temperature of 1 kilogram of water at its greatest density 1° Centigrade and the small (g.-calorie, written also, calorie, with a small c), the amount required to raise the temperature of 1 gram of water 1° Centigrade.

The British thermal unit represents the amount of heat necessary to raise the temperature of 1 pound of water at its point of greatest density 1° Fahrenheit. In practice, however, the standard for density is based on a temperature of 60° F. and a barometric pressure of 30 inches.

The number of heat units obtainable from a given gas can be determined by chemical analysis but, while theoretically a perfect method, it will not do for every-day practice by gas companies and government inspectors, as the process is too slow and expensive and a skilled chemist must be engaged for the purpose.

Therefore, inventive genius has designed a number of forms of apparatus, called calorimeters, for determining the heating value quickly and accurately and in a simple manner not requiring operation by an expert.

The degree of accuracy with which any one of these instruments indicates the number of heat units, that is, its efficiency, depends not so much on the operator as on perfection of design and construction.

In this respect calorimetry has the merit over photometry of giving a truer indication of the quality of the gas, as the personal factor so variable in making observations of the photometer sight box disc for the point of equal illumination is practically excluded in calorimetry, the determination under proper working conditions being based entirely on the results of mechanical operations, viz., noting thermometer and barometer indications, weighing the water heated and measuring the gas consumed. These tests may be very accurately made, with a little practice, by any intelligent employee of the gas company.

CALORIMETERS.

There are many different types of calorimeters based on entirely different principles, some applying the heat of the gas being tested directly to water running through the instrument, and others applying it to some other medium.

The most important and most used of the former class, viz., the continuous flow, water-heater type, is the Junkers design.

ORIGINAL JUNKERS CALORIMETER.

The original German form of this instrument has been in extensive use in Europe and America for many years and on account of its high efficiency has been generally favored by the experts.

In the proceedings of the American Gas Institute for 1908 and 1909 are found complete reports of investigations carried out by and under the direction of Prof. Kowalke of the Chemical Engineering Department of the University of Wisconsin.

We quote the following in reference to the original German Junkers Calorimeter:

> Among many conclusions drawn from these investigations the following are especially important.
>
> (a) The efficiency of the Junkers Calorimeter is 99.5 per cent. when operating conditions are as follows:
>
> (1) Temperature of inlet water and exhaust gases the same as that of the room, when applying electrical energy.
>
> (2) Rate of combustion of the gas from 7½ to 8½ cubic feet per hour.
>
> (3) Difference in temperature between inlet and outlet water from 15 to 16 degrees F.
>
> (b) The most extreme variations in humidity of gas and air supply may cause variations in heating value of from —5.90 B. t. u. per cubic foot to +0.858 B. t. u. per cubic foot. (All gas volumes measured at 60 degrees F. and 30 inches of mercury.)
>
> (c) The Junkers calorimeter is the most desirable calorimeter for the determination of the heating value of municipal gas.
>
> (d) The meter should be frequently calibrated.
>
> (e) High grade thermometers should be used.

In these reports, however, it was recommended that changes and improvements be made to facilitate operation without reducing the efficiency of the instrument.

These suggestions were taken up by us and an improved type of the Junkers Calorimeter designed.

AMERICAN JUNKERS CALORIMETER.

Tests by American Gas Institute.

Having completed some of these instruments with the desired changes and improvements we found they met with general approval and in 1911 we submitted one to the American Gas Institute for careful examination and test. The Committee on Calorimetry rendered the following report on it:

> That of the American Meter Company gives results sufficiently correct for general use and adoption by the members. This instrument embodies the general design of the original Junkers instrument and seems to have included the elements that have given that calorimeter its general high efficiency. It is modified, however, according to the recommendations submitted in the Committee's Report for the years 1908 and 1909 and is provided with accessories that read directly the heating value, making all measurements in English Units.

Later Tests by the Institute.

In 1912 a later improved model was tested for efficiency with a number of other types and the results were very gratifying as shown by Report of the Committee on Calorimetry for that year, from which we quote:

> (3) *The American Meter Co.'s Calorimeter.*
>
> The American Meter Co.'s calorimeter No. 122 used in this investigation was loaned by the American Meter Co. of New York City. In all fundamental principles this calorimeter is a Junkers calorimeter. However, a considerable number of minor changes have been made which facilitate the operation of the instrument. These changes may be summarized as follows:

(1) Both thermometers are on the same level.

(2) Special gaskets are provided for securing the thermometers in place.

(3) The absorption chamber can be removed from the outer shell of the instrument, thus facilitating cleaning operations.

(4) Baffle plates are provided for the burner.

(5) The burner has a flat, circular base so that the burner will remain in an upright position when unsupported.

(6) The burner top screws on to the stem.

(7) An adjustable mirror enables the operator to note the gas flame.

(8) A small plumb bob is provided for leveling the instrument.

(9) The position of the damper is indicated by a pointer and scale.

(10) A three-way cock provides a means of directing the outflowing water either to the receiving bucket or to the drain.

(11) A vent is provided to obviate the trapping of air around the three-way cock.

Inasmuch as the basic principles of the instrument are the same as both forms of the Junkers calorimeter, it was not deemed necessary to work out the proper rate of combustion of the gas or the proper relation between the temperature of inlet water and room temperature before making comparative tests.

The only work done with this instrument was to make two series of comparative tests between it and the Junkers No. 872.

Conditions of Tests.

Both calorimeters were operated under identical conditions, these being the standard conditions for the operation of the old form of Junkers Calorimeter, as previously determined in this investigation. Both

calorimeters were operating continuously and simultaneously throughout each series of tests. Baffle plates were placed upon the stems of both calorimeter burners. Natural draft used.

(Here follow details of tests.)

Summary of Results.

From the above series of tests the following conclusions can be drawn:

(1) When operated under the standard conditions for the old type of the Junkers calorimeter the American Meter Co.'s calorimeter gives the same efficiency as the Junkers calorimeter.

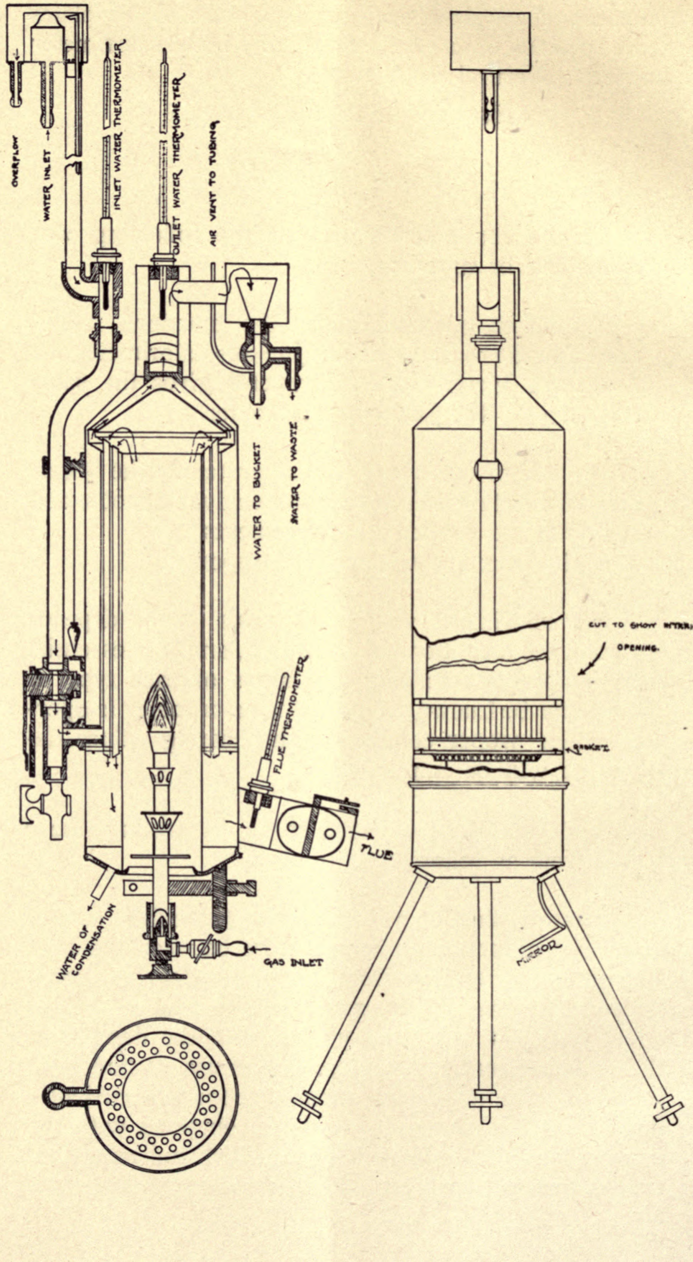
(2) All of the changes enumerated at the beginning of heading (3) appear to be advantageous, and can truly be termed "improvements."

Quoting again from the Committee's report:

A gas calorimeter will give various results dependent upon the conditions of operation, and it is essential that the proper working conditions of each type of calorimeter be known. Unless the calorimeter is operated under proper conditions, the heating values determined will be unreliable.

The standard conditions referred to as in testing the original Junkers type were as follows:

The rate of flow of gas was seven (7) cubic feet per hour; the difference in temperature between the inlet and outlet water was from 15 to 16 degrees; room temperature was 75 degrees. In this and all subsequent tests with the Junkers No. 872, the damper in the exhaust outlet was closed, because it had been found in previous investigations that for this particular instrument higher results could be obtained with the damper closed than with it open, which indicated that combustion was perfect with the minimum excess of air.


OVERFLOW
WATER INLET
INLET WATER THERMOMETER
OUTLET WATER THERMOMETER
AIR VENT TO TUBING
WATER TO BUCKET
WATER TO WASTE
FLUE THERMOMETER
FLUE
WATER OF CONDENSATION
GAS INLET
CUT TO SHOW INTERIOR
OPENING.
MIRROR

GENERAL DESCRIPTION AND IMPROVEMENTS.

The general design of the instrument is shown in the line cuts opposite giving sectional views and in the illustrations of complete sets of apparatus herein.

The calorimeter jacket is constructed of polished sheet copper, tinned inside and nickeled outside to prevent radiation of heat. The tubes are of the best quality copper, tinned.

The most important improvements made in this part of the apparatus are these:

Three-way cock on outlet weir, so water can be readily diverted to waste or pail,

Baffle plates fitted to the burner,

Two sizes of burner tips provided, these being set in sockets which screw on the burner,

Burner constructed with base to stand on when withdrawn from instrument,

Mirror for observing the flame, making it unnecessary to withdraw the burner for the purpose, and enabling the operator to properly adjust the air supply,

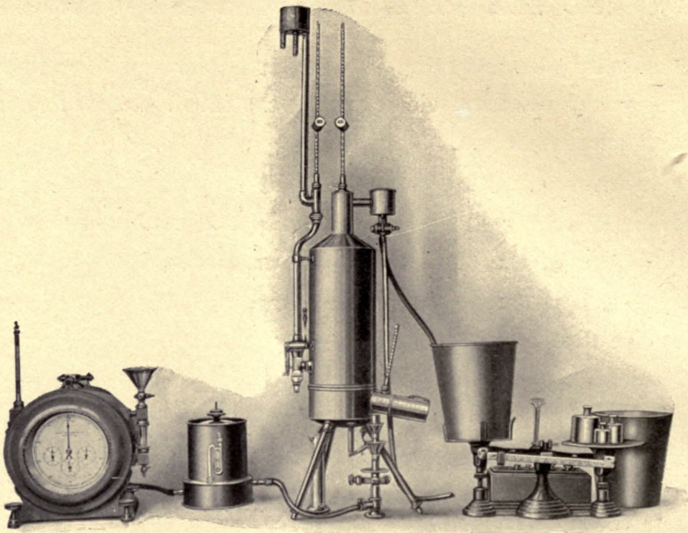
Water thermometers set close together and at the same level,

Thermometers set in screw sockets instead of rubber corks, so bulbs can always be kept at the same depth, reducing the liability of breakage in use.

Exhaust tube fitted with damper on the axis of which is a hand moving over a graduated arc, thus enabling the operator to observe the exact position of the damper at all times and re-set it correctly,

A small plumb bob hung from the side of the instrument to level it, avoiding the necessity of placing a level against the different sides of the body,

The body put together with screws instead of being soldered, so that it can be taken apart and any trouble remedied or any part cleaned.



COMPLETE OUTFITS.

The complete apparatus and accessories are listed in sets as follows and can be furnished as desired:

No. 300 Set.

Calorimeter complete with all improvements previously enumerated.

2—18″ highest grade calorimeter thermometers for water, made by Hohmann & Maurer Mfg. Co., to specifications of Committee on Calorimetry of the American Gas Institute, graduated in tenths of a degree Fahrenheit and furnished with telescopic sights and manufacturers' certificates of comparison with Bureau of Standards certified thermometer.

A high grade special exhaust thermometer.

Tinned brass wet test meter No. 613 type, 1/10 cu. ft. per revolution, index reading 1/1000th of a cu. ft. to 100 cu. ft., fitted with thermometer, levels, leveling screw feet and outside waterline gauge with marker of special design approved by the U. S. Bureau of Standards for accuracy and stability.

Wet regulator of tinned brass, nickeled outside, with pressure gauge fitted with nickeled scale.

Specially made equal arm balance weighing to one-thousandth of a lb. with 1/10 lb. beam, agate bearings and forked pailholder, arranged to balance the empty pail.

Two copper water pails tinned inside, for weighing the water.

Set of cylindrical brass weights.

100 cc. glass graduate for condensation.

12 ft. pure rubber tubing.

Correction table for temperature and pressure.

No. 301 Set.

Including No. 300 set with the following additions and accessories which, while not necessary for accurate operation, add to its convenience and are very desirable.

Very fine equal arm balance with agate bearings, brass weight plate, forked pailholder, one-tenth pound beam, weighing to the thousandth part of a pound, adjusted to balance the empty pail and furnished with a fine set of brass weights with lifting knobs in block.

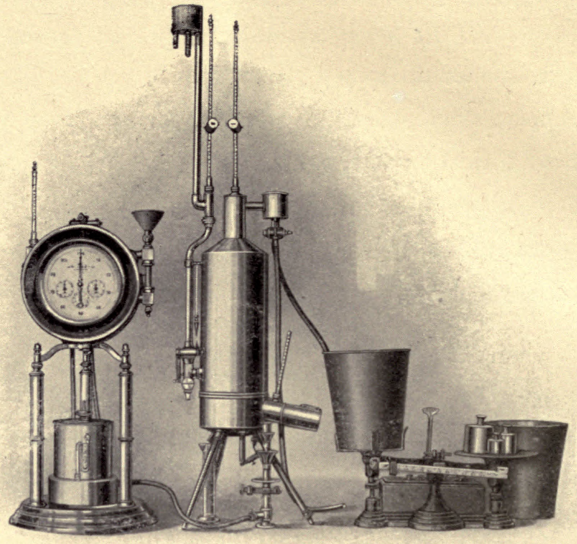
Brass casings for the water thermometers, design as suggested by the Bureau of Standards to prevent accidental breakage as far as possible without affecting accuracy or making reading difficult.

Six inch Siphon Pressure Gauge for use on meter or gas supply line.

Meter fitted with bell, ringing automatically at each revolution of large pointer, indicating the registration of 1/10 cu. ft. of gas without the operator having to watch the meter.

Heat Value Computer, designed and patented by the United Gas Improvement Co., which saves much time in calculation of results and prevents errors.

Record card loose-leaf binder with 25 card forms on which to enter results of tests.



No. 302 Set.

We have also designed a nickeled stand as illustrated for mounting the meter above the governor. This saves space and gives the apparatus a very neat appearance, the meter in this model being enameled white and all gas connections made with flexible metal tubing.

This set includes the No. 301 set with this stand, etc., as described.

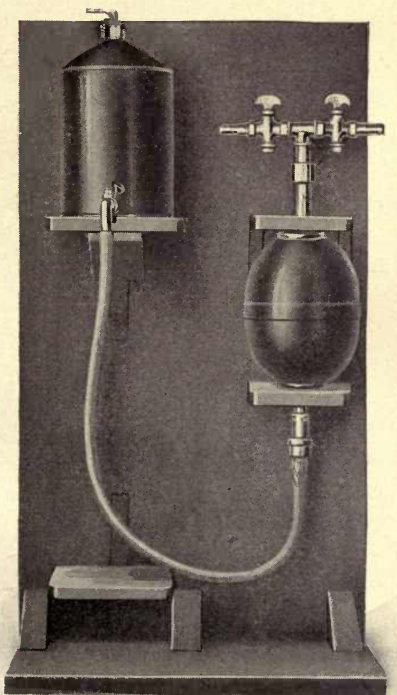
ACCESSORIES.

Wooden Carrying or Packing Cases, strongly made, can be furnished in sets of 2 to contain the entire apparatus.

Leatheroid Trunks can also be furnished for the use of traveling inspectors to further protect the apparatus when packed for shipment in the wooden cases.

Barometer. We recommend as the most reliable and suitable for use with the calorimeter outfit the Mercurial Observatory Barometer, Weather Bureau type, which can be furnished on request. This is fitted, unless otherwise ordered, with a scale graduated in inchs and tenths and with the 1/100″ Vernier reading to thousandths of an inch. It can also be furnished with scale in millimetres or inches and millimetres.

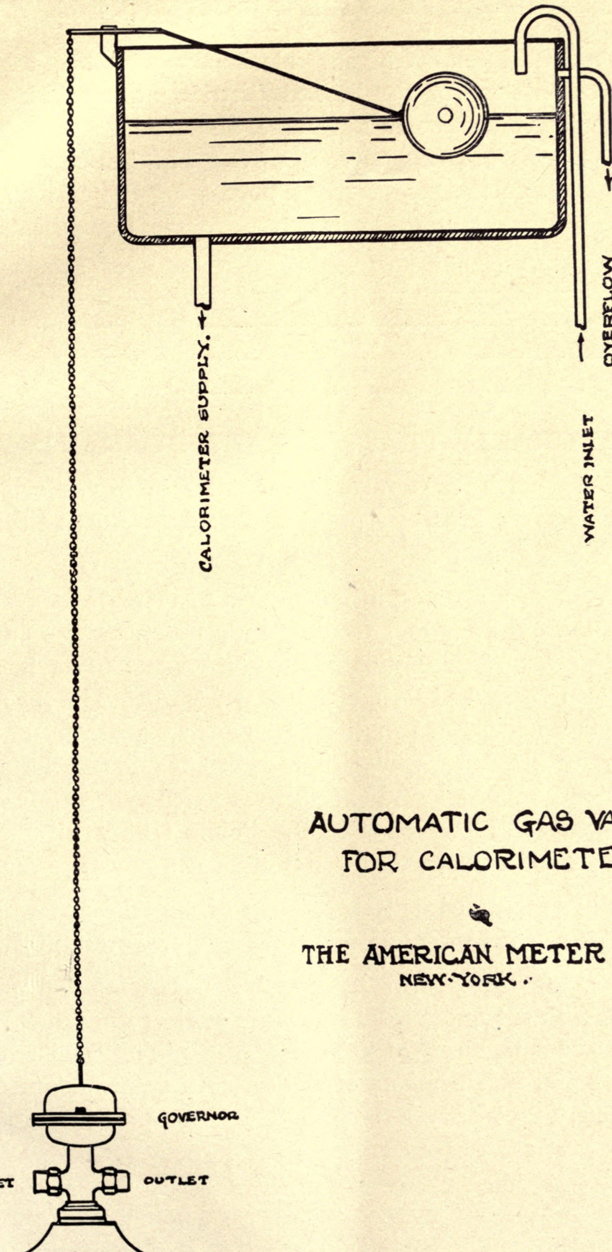
Hygrometer. The Hygrodeik is the ideal Hygrometer for all industrial or domestic uses. It is wet and dry bulb hygrometry minus the tables and computation. The chart is a condensed, graphic presentation of all the facts given in the Hygrometer tables. While complicated in appearance, it is simplicity itself. This chart was plotted from standard tables compiled for use with the Mason (wet and dry bulb) Hygrometer, and can be relied upon as being correct. The lines on the chart are adapted to show graphically the Relative Humidity, Dew Point, absolute amount of moisture present and the weight of water in each cubic foot of air, expressed in grains.



Testing Bottle. For frequent and accurate testing of the meter it is best to use a 1/10 cu. ft. bottle. This is made of polished copper and is mounted with a copper tank fitted with thermometer on a wooden stand as illustrated (Cat. No. 202). It is furnished with Bureau of Standards certificate of accuracy.

AUTOMATIC GAS SHUT-OFF.

Having had called to our attention many instances of injury to calorimeters occurring through the water supply from the tank running out while the gas continued burning, we have devised a shut-off valve for the gas, mounted on stand as illustrated, this valve being open while the water in the tank remains at sufficient height but closing automatically and cutting off the gas supply by connection with a ball float in the tank when the water runs too low.



AUTOMATIC GAS VALVE
FOR CALORIMETER.

THE AMERICAN METER CO.
NEW-YORK.

TESTS BY PUBLIC SERVICE COMMISSION NEW YORK

We have had a number of our calorimeters tested by the Public Service Commission for the Second District, State of New York, for use by gas companies in this State, although the testing of gas for heat value is not compulsory as yet. The last report of efficiency as made to the gas company purchasing the calorimeter, of which we obtained a copy by courtesy of the Commission, is as follows:

Efficiency	99.8%
Gas Rate	6 ft. per hour
Damper	closed
Water Quadrant	60-¼

FAVORABLE FEATURES AND GUARANTEE.

One of the particularly favorable features in this calorimeter is that there are very small variations in the temperature of the outlet water during a run of tests.

We have been unceasing in our efforts to increase in every possible way the efficiency and facility of operation of this apparatus and have welcomed suggestions from the experts using it, so that the American Junkers Calorimeter is now regarded with the greatest favor by those interested in the gas industry generally and is in continuous use in the various works controlled by the large operating companies throughout the country, as well as with any number of small companies and many of the Public Utility Commissions, State and City Gas Inspectors.

It is fully guaranteed as to perfection of material and workmanship, as well as efficient action under the proper working conditions.

Inquiries for prices will be greatly appreciated and promptly replied to, with net quotations, which are subject to change without notice, in order to meet fluctuating cost conditions and cover improvements and modifications of design as they are adopted from time to time.

RECOMMENDATIONS OF AMERICAN GAS INSTITUTE.

The following extracts from the Supplement to Report of the Committee on Calorimetry of the American Gas Institute for 1912 give authoritative information on the testing of gas for calorific value.

It will be noted by comparison of the foregoing description of our apparatus with the specifications given by the Committee covering the necessary requirements which a calorimeter outfit of the Junkers type should satisfy that our improved calorimeter with meter, scale and governor more than meet these requirements, so that the specifications really are a very good detailed description of it, with the exception only that in several respects our calorimeter sets are of finer grade than the specifications require.

The heating value of a gas, as indicated by the calorimeter, when operated according to these instructions, is that defined and adopted by the American Gas Institute and given in Volume III, 1908, page 383, as follows:

"The heating value of a gas is the total heating effect produced by the complete combustion of a unit volume of the gas, measured at a temperature of 60 degrees Fahrenheit, and a pressure of 30 inches of mercury, with air of the same temperature and pressure, the products of combustion also being brought to this temperature.

"In America the unit of volume is the cubic foot and we recommend that the heating value be stated in terms of British thermal units per cubic foot of gas."

It is known that the heating value thus determined by the calorimeter and defined usually as the gross heating value, is not always the same as the theoretical value, as the percentage of humidity of the atmosphere introduces an error in the reading of the instrument that may make it read slightly higher, or lower, as the case may be.

This error may be corrected so as to make the gross heating value equal to the total heating value, when the final reading is obtained, by applying the corrections shown in Table I, attached, which was submitted to the Institute by Dr. E. B. Rosa, in his paper, "The Legal Specifications for Illuminating Gas."

Another factor that influences to a considerable degree and which should also be taken into consideration, when a correction is applied for atmospheric humidity, is the amount of air admitted with the gas into the calorimeter. This quantity should be enough to assure perfect combustion of the gas, and maintain the excess air at a minimum. It is controlled by the position of the damper—in a majority of cases—which will be explained later. In a number of instances, this excess air approximated 30 per cent. for ordinary illuminating gas, and this figure is used for average conditions.

The so-called net heating value of the gas may be determined by deducting from the gross heating value, the latent heat of the water condensed in burning one cubic foot of gas. No correction for atmospheric humidity should be applied in determining this value.

To facilitate the operation of calorific determination of gas in commercial practice, we recommend the use of accessories expressing the result direct in English units. As the British thermal unit has been adopted as the expression of heating value, and, as the cubic foot of gas is used as the unit of volume, the heating value of the gas is therefore expressed in British thermal units or B. t. u.'s per cubic foot. If, therefore, the various measurements are made with English measuring instruments, all inconvenience of using a mixture of metric and English units, or a reduction of a portion of the data from metric to the English system will be avoided.

Therefore, in determining the calorific value of gas we recommend:

The measuring of the gas in cubic feet.

Taking all temperatures of air, gas and water with Fahrenheit thermometers.

Weighing or measuring the water in pounds and hundredths of a pound.

Correction of the volume of the gas to standard volume, as expressed when measured at a temperature of sixty (60) degrees Fahrenheit, and barometric pressure of thirty (30) inches of mercury.

Expressing the result of all calorific determinations in British thermal units (B. t. u.'s).

SPECIFICATIONS TO BE ADOPTED IN SELECTION OF INSTRUMENT.

(From Report of American Gas Institute.)

The following instructions cover the precautions to be taken in selecting and operating calorimeters of the Junkers type, which are those in general use throughout this country.

Calorimeters of Junkers Type.

The calorimeter proper should be an instrument that transmits directly the heat evolved by the burning gas to a quantity of water. The calorimeter should be accompanied by accessories that shall measure definitely the gas burned, the water heated, and the temperatures of the gas, water, air and exhaust products.

The apparatus should be designed to give a constant head of water on the calorimeter. This head should be maintained by having a weir overflow on the inlet at some distance above the top of the calorimeter, and a weir overflow at the outlet. The rate of water flow through the calorimeter should be capable of regulation and adjustment.

The calorimeter should be so built that the water will circulate freely, and will be equally distributed throughout the apparatus. Baffle plates should be so arranged that the water will be thoroughly mixed before coming in contact with the bulb of the outlet thermometer, insuring a correct average reading. The design should be such that air pockets cannot form in the water space of the calorimeter.

The calorimeter should be preferably made of bright polished metal, air jacketed in all its parts.

There should be a damper in the exhaust gas flue which can be easily adjusted, and made to control the amount of excess air passing through the calorimeter.

The calorimeter should be mounted at a height sufficient to make it easy to put the burner in place, and on legs with a spread great enough to insure a firm base.

It may prove desirable in practice to have water thermometers on the same level, to facilitate readings, as recommended by the Calorimetry Committee of the American Gas Institute. The openings for thermometers should be large enough to easily insert the thermometers.

Gas Meter.

For a meter, it is preferable to use a wet meter, and one registering one-tenth cubic foot of gas per revolution.

The large dial should be divided into 100 equal parts, with every tenth part distinctly marked to facilitate reading. In addition to the large dial, there should be a smaller dial to register the number of revolutions of the large hand; this dial should register tens, units and tenths of a cubic foot.

The face of the meter should be enameled and no glass used on the front, thereby preventing error due to parallax. The face of the meter should be easily removable, in order to get at the shaft and the stuffing box on the shaft. This stuffing box should be of a size large enough to be easily packed.

The large hand of the meter should be well pointed, and not extend to the outer end of graduations of the meter dial. The meter should have leveling screws.

Two leveling tubes, placed at right angles to each other, should be securely fastened to the top of the meter.

The meter should have an outside gauge glass showing the water level. This glass should not be less than ⅜ inch, nor more than ¾ inch, inside diameter, as it is necessary to have the glass large enough to be readily cleaned, and small enough that the meniscus formed by the water can be accurately read. The openings from the gauge to the meter should be unobstructed, and of a size to correspond with the size of the gauge glass. A fixed point to show the correct water level, reading to the bottom of the meniscus, should be put on the outside of all water level gauge glasses.

For convenience, a standard 3-light meter union should be used on all meters, and hose nipples for ⅜ inch hose should be furnished with the unions.

The meter should be provided with an opening for the addition of water when needed. This can be done by using a pet cock, with a small covered funnel mounted on top, connected to the top of the gauge glass support.

An opening must be left for a thermometer in or near the gas outlet. This thermometer should have a metal case and read to one degree Fahrenheit, with a range of from about 50 to 100 degrees, and accurate to within one-half degree.

An opening with a plug connection should be left on the bottom of the meter to drain it when so desired.

The number of joints liable to cause gas or water leakage should be reduced to a minimum.

Gas Pressure Regulator.

The pressure of the gas when burning in the calorimeter should be absolutely uniform to obtain correct results, and any small regulator that will maintain this uniform pressure will be satisfactory. We recommend the use of a small wet governor, similar to the one supplied with the Junkers Calorimeter, placed between the meter and burner. This will give excellent regulation, and will operate without chattering. Such a regulator should be constructed so as to be readily weighted for altering the delivered pressure.

The gas delivered to the meter should be governed by means of some form of service governor so as not to exceed a pressure of about two inches, while being measured.

Burners.

The burner should be a long tube Bunsen, having a spreader on top, and adjustable air mixer which can be easily reached when burner is in position in the calorimeter. The burner should be provided with a stop-cock. The burner should be attached to the calorimeter in such a way that the gas flame cannot impinge on the interior body of the calorimeter, and when the burner is set at its correct position, well up into the combustion chamber, it should be so fastened that it cannot be accidentally shifted. The condition of the flame should be observable by the operator, either directly or by means of a reflecting mirror.

It has been found, by investigation, that the adoption of suitable baffle plates attached to the stem of the burner prevents some radiation of heat downward from the combustion chamber and therefore increases by several B. t. u.'s the observed heating value, of the gas.

Thermometers.

Accurate thermometers are the most important accessories to correct calorimetry.

The thermometers for reading water temperatures should be of high grade quality, and should read accurately within one-tenth of a degree Fahrenheit.

The thermometers should be graduated from 60 to 110 degrees Fahrenheit, each degree to be divided into tenths, with short, distinct graduations. The thermometers should be so accurately made that in ordinary commercial work corrections may be neglected. With each thermometer should be provided a calibration curve, which should enable very accurate results to be obtained whenever it is deemed necessary to make these corrections.

This matter of high grade thermometers for calorimetry work has been taken up with several thermometer makers by your Committee, and thermometers are now being supplied that accord to its recommendations. The thermometers have a range of from 60 to 110 degrees Fahrenheit, and are graduated to one-tenth degree. Some of these thermometers were made having an auxiliary division at 32 degrees Fahrenheit, which was deemed convenient for checking the ice point; but later it was found advisable to omit this auxiliary graduation. These thermometers are carefully made and have a bore that is exceedingly uniform and accurate, and are supplied with most makes of calorimeters.

The error of one-tenth degree above mentioned may seem to be a small matter, and it is in most measures of temperature, but when the calorific value of an artificial gas is determined with a rise in the water temperature of 15 degrees Fahrenheit, a difference of one-tenth degree means an error of 1/150 of the total heat of the gas, or about four (4) B. t. u. 's. If the total rise in temperature is less than this the error introduced is greater.

When doubt arises as to correctness of thermometers, we recommend their calibration by the National Bureau of Standards at Washington.

Telescopic sights for reading thermometers should be provided, as much more accurate readings can be obtained in this way.

Barometer.

Corrections for variation in barometric pressure should be made in measuring the volume of the gas. This pressure should either be obtained by means of a mercury column barometer or by a recently calibrated aneroid barometer. Where it is possible barometer readings should be checked occasionally with readings of the Government Weather Bureau of the city in which the readings are made. Where no barometer is available, it may be possible to get fairly accurate figures on pressure by obtaining from the local Weather Bureau the barometer readings for the day, and correcting for variations in elevation.

Water Supply and Measurement.

The control of the temperature of the water supply is very important in calorimetry, and this temperature should be approximately that of the room in which the observations are being made. Water obtained from an ordinary house piping system is apt to be variable in pressure and temperature, due to the uneven consumption in other parts of the building, and possible exposure of the water main to the extreme temperatures of the ground or atmosphere. This control of temperature or pressure may be readily obtained by providing a permanent water supply tank in the upper part of the calorimeter room, that will contain enough water to enable the readings for the day to be made. A flat tank of large horizontal area is preferable to a deep vertical tank. The exposed surface allows the water to come to the temperature of the room more readily, while the shallow depth has less effect on the head as the water is being used. A large galvanized house boiler has been satisfactorily used for this purpose.

Should a number of continuous readings be made that will require more water than is contained in the overhead tank, a simple coil gas water heater may be employed to raise the temperature of the water supply to the overhead tank, so that it will enter this tank at approximately the temperature of the room. The tank will then act as an equalizer and assist in maintaining a uniform temperature and pressure of water entering the calorimeter.

Water may be collected and weighed in thin sheet metal containers, holding about nine (9) pounds of water. This size container will hold all the water required in burning 0.2 of a cubic foot

of ordinary illuminating gas, with a range of about fifteen (15) degrees Fahrenheit in temperature between the inlet and outlet water. The scales, or balance, employed should have a capacity of at least ten pounds, should read to 1/100 of a pound, and should be calibrated and made correct.

Should it be desired to measure the water volumetrically, instead of weighing it, graduated vessels may be employed that will read accurately the water passed through the calorimeter to within 1/100 of a pound. But the use of such graduates introduces other errors that should be avoided if possible.

Gas Piping and Tubing.

Gas connections for a calorimeter should consist of metallic piping or tubing where possible; rubber tubing, however, is generally found most convenient to use in temporary work, but in all cases the lengths used in conducting the gas should be as short as possible, and they should be thoroughly saturated with gas before a test is made.

Calorimeter Cabinet.

To facilitate the operation of the calorimeters at the various gas plants, the calorimeters should preferably be installed in a cabinet, similar to that recommended in the Report of the Calorimetry Committee as contained in the *American Gas Institute Proceedings,* Vol. IV., 1909, pages 205 and 206. This sketch represents a typical cabinet, suitable for use in some convenient building, either at the gas works or gas office, and of such a design that when the calorimeter is once placed and connected up, it may be kept clean, protected and ready for use at all times. The details, however, may be modified to suit local circumstances.

In construction, the cabinet should be made as dust tight as practicable. Where there is not enough head room for a vertical sliding door, horizontal sliding or folding doors may be substituted. This cabinet should provide for an overhead water tank, and may be most conveniently located adjacent to a sink and water supply.

The gas supply line to the calorimeter should have a purging connection. All cocks controlling the gas and water supply should be inside of the cabinet, and the cabinet should be kept closed and locked when not in service.

This cabinet should not be near any gas flame, heating register or other radiator; direct sunlight should not be allowed to strike upon it, but the thermometers and meter shall receive sufficient reflected artificial light to enable them to be easily read. Since drafts must be rigorously excluded, it is better, wherever possible, to set aside a room solely for the use of the calorimetric outfit.

The adoption of such an installation will enable a calorific reading of the gas to be made in a very short time, and will warrant the best of care being taken of the calorimeter and its accessories.

DIRECTIONS FOR ERECTING AND OPERATING.

(From Report of American Gas Institute with Addenda.)

On unpacking the calorimeter see that all parts are received and in good condition. Clean it inside and outside and be sure it is free of all packing material.

Set up the apparatus as shown in cuts of the different sets.

Screw on the inlet water pipe and see that the air vent tube is in its place in this pipe.

Level the calorimeter by means of the screw feet and plumb-bob.

Connect the center hose nipple on the inlet weir with rubber tubing to the water supply and the side connection to the sink to carry away the overflow.

Connect the tubing for water running to weighing pail to the vertical nipple on the 3-way cock on the outlet weir and for the waste to the side nipple.

Handle the thermometers with the greatest of care.

Screw the 32° to 100° thermometer on the inlet water pipe and the 60° to 110° thermometer on the top of the instrument for the outlet water. Screw the small thermometer in place on the exhaust flue.

Place the two telescopic sights in position on the water thermometers, being very careful not to break them off by pressure against the sights.

Connect the meter to the governor and the governor to the burner with short pieces of rubber tubing (Sets Nos. 300 and 301), or with flexible metal tubing having coupled ends (Set No. 302).

The calorimeter should be set up in a quiet, light and well ventilated room or cabinet, which is free from draughts and in which the temperature can be maintained constantly at not less than sixty degrees Fahrenheit. The room should be provided with a sink and with a good supply of running water. It is advisable to have a large shallow overhead covered tank, from which the water supply can be taken. Should the tank capacity be small and not hold enough water for a prolonged series of readings, a small gas water

heater may be employed as already noted to bring the water to approximately the room temperature. It is desirable to use water in the calorimeter that is clear and free from suspended matter, therefore, a filter should be installed in the water supply line before it enters the overhead tank.

If only a single test is desired, gas may be taken from the house piping, but if an average value is required, a small gas holder, or averaging tank, should be used, and the gas flowing into the holder adjusted to a rate of flow to just fill it in the time during which the sample is to be taken. Care should be taken to have a short service to this holder in order that an average sample of gas may be obtained, and if the sample be taken from a line on which there is no considerable consumption, see that this line is thoroughly purged before sampling. It is recommended that the gas be metered at a pressure not to exceed two inches of water; if this is not obtainable, it is advisable to insert a holder or diaphragm governor in the supply line to reduce the pressure to within this limit.

Set up the calorimeter so that the overflow and outlet water can be easily led to the sink. Make water connections with rubber tubing, being careful not to cramp the tubing. To avoid air currents caused by the movement of the observer's body, set up the calorimeter so that the water supply and waste may be easily adjusted and that all temperatures may be readily observed. Lead the outlet water to a waste funnel supported a little above the top of the copper or glass container used in collecting the water, so that the water can be shifted from the funnel to the container and back without spilling.

Set up the gas meter facing the observer and level it carefully. Then adjust the water level of the meter, both inlet and outlet being open to the air. To do this, remove the plug from the dry well, open the funnel cock and disconnect the tubing on the outlet of the meter. Add water through the funnel or remove by the cock under the gauge glass until the lowest edge of the meniscus just touches the scratch on the gauge glass, or is even with the fixed marker. If the meter has been filled with fresh water the gas must be allowed to burn at least two hours before making a test. When the water in the meter is saturated with gas, twenty minutes should be sufficient,

Fill pressure regulator with water, about ¾ full, then connect it to the calorimeter burner. Metallic tubing is preferable, but when rubber tubing is used to connect meter, pressure regulator and burner, connections should be as short as possible, and should be saturated with the gas.

Turn on gas and allow it to burn for 5 to 10 minutes with the burner on the table. Shut off gas at burner and watch hand on meter for leakage. Be sure that all leaks are stopped before attempting to make a test. Start water running through the calorimeter at a rate of about three pounds per minute. Then regulate the gas to flow at the rate of four to seven feet an hour, as may be found by experiment to give the highest result with the gas to be tested, admitting enough air through the burner so that the flame shows a faint luminous tip, then insert the burner as far up into the combustion chamber as the bracket permits, and observe again the condition of the flame to see that it is all right, using a mirror.

The excess of air passing through the calorimeter is controlled somewhat by the position of the damper in the exhaust port, and the best results are obtained by having the excess air as low as possible and still maintaining complete combustion of the gas. To determine this position of the damper, some experimentation may be necessary. Operate the calorimeter until a thermal balance is established on the inlet and outlet water thermometers. Start with the damper closed, then open slightly, observing carefully the outlet thermometer. When this thermometer reads at a maximum—or in other words, when the greatest rise in temperature is given to the water, which is presumably passing through the calorimeter uniformly—the damper is in approximately the correct position for the amount of gas being burned, and the excess air necessary for perfect combustion is at a minimum.

Water should be regulated so that there is a difference between the inlet and outlet temperatures of about 15 degrees Fahrenheit. The temperature of the inlet water should vary but little when an overhead tank is used and the water maintained at room temperature. Be sure that both overflows are running.

Before making the test, the barometer, temperature of the gas at the meter, temperature of room and temperature of exhaust products should be recorded. It is desirable to have the temperature of the inlet water and temperature of exhaust products as nearly as pos-

sible at room temperature, in order to establish more nearly a thermal balance—the difference in these temperatures should never exceed five degrees.

Next allow the gas to burn in the calorimeter until a thermal balance is established, or until there is the least change in the inlet and outlet waters.

The test may now be started by shifting the outlet water by the three-way cock from the funnel to the container just as the large hand on the meter passes the zero point. Readings are then made of inlet and outlet thermometers, making the readings as rapidly as the observer is able to record them during the consumption, preferably of two-tenths of a cubic foot of gas. At least ten readings should be made of both inlet and outlet water temperatures. Water is again shifted from the container to the waste funnel as the hand passes the zero point the second time. Water is then weighed or measured. The uncorrected heating value per cubic foot is obtained by multiplying the difference of the averages of inlet and outlet temperatures, by the number of pounds of water and by dividing by two-tenths. This quantity is divided by the correction factor for barometer and temperature, obtainable from tables, to give the heating value at 30 inches pressure and 60 degrees Fahrenheit. The weight or contents of container should be obtained while the inside is wet. This may be done by filling it with water, emptying and shaking for about five seconds in an inverted position. This will do away with any correction where several consecutive tests are required with same container.

A second, and perhaps a third test is advisable, and these should be made without disturbing the existing conditions, provided all readings are within the above prescribed limits. In practice the operator should get consecutive results on the same holder of gas within ten (10) B. t. u.'s. Under such conditions an average of the results may safely be taken.

Results as Obtained by Calculation.

The method of calculating the calorific value of the gas from the observations indicated is very simple when all readings are made in English units, as recommended, and entered in some form conveniently arranged. A simple record sheet is shown herewith, a convenient size for which is five by eight inches.

No. ....

GAS CALORIMETER READINGS

....

PLACE OF TEST .... **DATE** ....

	TIME	TIME	TIME
Kind of Gas			
Calorimeter, Kind			
Barometer Reading *			
Temperature of Gas *			
Correction Factor			
Temp. of Atmosphere			
Temperature of Exhaust			
Condensed Water Collected			
Time one Rev. of Meter			
Gas Consumed Dur'g Test*			
Rate of Combustion			
Weight of Water *			
Per cent. Atmos. Humidty			

TEMPERATURES OF WATER		INLET	OUTLET	INLET	OUTLET	INLET	OUTLET
READ AT LEAST TEN TIMES DURING TWO REVOLUTIONS OF METER HAND	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
Average Temperature							
Thermometer Correction							
Actual Temp.							
Rise in Temp. *							

B. T. U. Recorded			
Cor. for Atmos. Humidity			
B. T. U. Corrected			

In using Heating Value Computer, take Figures Indicated by Asterisk*

.... **OBSERVER**

The averages of the inlet and outlet water temperatures are determined and necessary corrections for thermometer errors are made. The difference in these averages should give the rise in temperature of the water. This rise in temperature of the water is then multiplied by the number of pounds of water passed through the calorimeter during the test.

The product of these two is then divided by the quantity of gas burned—0.2 of a cubic foot. This quotient will give the heating value of one cubic foot of gas in B. t. u.'s at the indicated temperature and barometric pressure. To correct this to 60 degrees Fahrenheit and 30 inches pressure, divide by the "Correction Factor" for the indicated temperature, and pressure as obtained from some standard table. [Printed on card sent with apparatus.] The final result will be the corrected heating value of the gas tested, in B. t. u.'s.

Expressing the above in a formula we have:

$$\text{B. t. u.'s per cubic foot} = \frac{W \times T}{G}.$$

W = weight, in pounds, of water passed.

T = the average difference in temperature, in degrees Fahrenheit, between inlet and outlet water.

G = corrected volume of gas burned, in cubic feet.

The correction for atmospheric humidity is made finally, if so desired.

Use of Computer.

The labor of making the calculations for determining the heating value from observations of a calorimeter may be lessened by the use of a heating value computer. The computer consists of a circular slide rule, with divisions corresponding to the readings made on the calorimeter. This computer gives the corrected heating value of a cubic foot of gas in B. t. u.'s, having the barometric pressure and temperature of the metered gas, and the difference in temperature between the inlet and outlet water, and the pounds of water passed. This computer is designed to operate within the limits of from 300 to 800 B. t. u.'s. Should a gas of a lower or higher heating value be measured, the computer can still be used by dividing or multiplying

one or the other of the factors in its computation. A cut of this computer can be found on page 373, Vol. III, *Proceedings of the American Gas Institute.*

Care of Instruments.

The calorimeter, being a delicate and sensitive instrument, should be very carefully cared for when not in use. If the instrument is set up permanently, provision should be made that it be not disturbed by anybody except the operator. If the instrument is not erected permanently, when dismantled it should be carefully cleaned inside and out and the thermometers removed and carefully packed in cotton.

It is advisable to inspect the calorimeter periodically to see whether the interior of the combustion chamber and tubes are free from carbon deposits and corrosion. This should be done once every few months and if it is found not to be clean, the interior of the combustion chamber should be washed or wiped out and the tubes should be cleaned. The latter may be easily freed of any deposit by using a wire brush cleaning rod, similar to that used in cleaning rifle barrels.

It seems hardly necessary that instruction should be given for the care of such an instrument, but certain precautions should be noted.

Precautions—"Don'ts."

Don't place lighted burner in calorimeter when water is not running through the calorimeter.

Don't shut off water while gas is burning, but if water is accidentally shut off, then shut off the gas quickly, to avoid breaking thermometers.

Don't move suddenly near instrument during test. Slight drafts thus caused will vary outlet readings and vitiate test.

Don't fail to check daily the water level in the gas meter.

Don't forget to test meter and all connections daily for leakages.

Don't erect the calorimeter too close to any heating or lighting appliances, where radiant heat might affect the readings.

Don't make the test with the inlet water temperature over 5 degrees above or below the temperature of the room.

Don't fail to fill the overhead tank with water when through testing, so that it will be ready for the next test.

Note.

That an error of one-tenth degree F. in the temperature of the water means an error of about 4 B. t. u.'s in the gas.

That an error of one-hundredth of a pound of water when burning 0.2 of a cubic foot of gas in the test means an error of about 0.9 B. t. u. in the gas.

That an error of one degree in the temperature of the gas means an error of about 1.8 B. t. u.'s.

That an error of one-tenth of an inch in barometer reading means an error of about 2 B. t. u.'s.

That when metering the gas, each additional inch of water pressure to which the gas is subjected means an error of about 1.5 B. t. u.'s.

TO ADJUST THERMOMETERS.

In case the mercury becomes lodged in the top of the thermometer, up-end the instrument, shake it gently downward holding it in one hand and striking the upper end against the palm of the other until the column runs down and joins the mercury in the top, then suddenly reverse the position of the thermometer to bring it top up and the mercury should all fall back into place.

If the mercury is not re-united by the above method heat the bulb very slightly while holding in the inverted position, holding a lighted match or small flame near it, being careful not to overheat. As soon as the sections join reverse the position as above instructed.

TO ADJUST BALANCE FOR WEIGHING WATER.

This is specially arranged to balance with empty pail on scale.

If scale is out of balance, due generally to the counters being out of level, it can be balanced quickly as follows:

Suppose the pail side is too heavy; with pail on pail side place enough lead foil on the weight plate to make scale balance; then unscrew the weight plate and drop the lead foil into the cup put there for the purpose. If scale is too heavy on weight plate side, remove a little of the lead found in the cup. See that the weight plate is screwed down tightly in its place.

It is best to have pail side a little heavy, so that the scale will drop down and rest there when not in use. Never put oil on any part of the scale.

CORRECTIONS FOR ATMOSPHERIC HUMIDITY.

(From Report of American Gas Institute.)

This correction is found to be the greatest when the percentage of humidity of the atmosphere is the lowest. The reason being that the relatively dry air entering the calorimeter causes to be carried out in the exhaust products a larger amount of the water in the form of a gas or vapor, that is formed by the combustion of the gas, and which does not condense, and, therefore, does not give up its latent heat to the calorimeter.

The humidity correction should correct for any discrepancy in water vapor carried in by the air and gas, compared with that carried out by the products of combustion.

Owing to the contraction in volume, during the combustion of ordinary illuminating gas and air, this discrepancy is practically nothing when the percentage of atmospheric humidity is about eighty per cent., at normal temperatures, and the excess of air introduced for combustion is about thirty per cent.

In correcting for atmospheric humidity it is assumed that the gas is saturated with water vapors—having passed through a wet meter. This assumption might not be absolutely true, but the percentage of saturation has been found always to be high, and as the volume of gas is only about one-eighth of the mixture, the error involved may be neglected.

Table I.—Corrections to Observed Heat to Get Total Heat Value. Air, Gas and Exhaust Must Be at the Same Temperature.

If 7 volumes of air per volume of gas are used.

Humidity	Room Temperatures.					
Per cent.	65°	70°	75°	80°	85°	90°
10	+4.8	+5.7	+6.7	+7.9	+9.2	+10.5
20	+4.1	+4.9	+5.7	+6.8	+7.8	+ 9.0
30	+3.4	+4.1	+4.7	+5.6	+6.5	+ 7.4
40	+2.7	+3.2	+3.7	+4.5	+5.2	+ 5.9
50	+2.0	+2.4	+2.8	+3.4	+3.8	+ 4.3
60	+1.3	+1.6	+1.8	+2.2	+2.5	+ 2.8
70	+0.6	+0.8	+0.8	+1.0	+1.2	+ 1.2
80	—0.1	0.0	—0.1	—0.1	—0.1	— 0.3
90	—0.8	—0.9	—1.1	—1.3	—1.5	— 1.9
100	—1.6	—1.8	—2.0	—2.4	—2.8	— 3.4

Note—These corrections are expressed in B. t. u. 's.

DIRECTIONS FOR USE OF ACCESSORY APPARATUS

Observatory Barometer.

To put up the barometer for observation, suspend the barometer by the ring in a good light near to and at the left side of a window and, when practicable, in a room not liable to sudden variations of temperature. Record the temperature and then by the screw lower the mercury in the cistern until the surface is in the same plane with the extremity of the ivory point, allowing ample time for the mercury to fall to the proper level in the tube. As this extremity of the point is the zero of the scale, it is necessary at each observation to perfect this adjustment. It is perfect when the mercury just makes visible contact. If the surface is lowered a little, it is below the point; and if raised a small amount, a distinct depression is seen around the point. This depression is reduced to the least visible degree. A few trials will show that this adjustment can always be made to a thousandth of an inch.

Never lower the mercury by the screw much below the ivory point while the barometer is in a vertical position, as when the mercury is low in the cistern, air will enter the tube unless held at an angle of about 45°.

The adjustment effected, bring the lower edge of the Vernier, by means of the milled heads, into the same plane with the convex summit of the mercury in the tube. Looking through the opening, with the eye on a level with the top of the mercury in the tube, when the Vernier tube is too low the light is cut off; when too high the light is seen above the top of the mercury. It is right when the light is just cut off from the summit, the edge making a tangent to the curve. An opal glass reflector placed behind, and also at the cistern, will be found to give a more agreeable light by day and is, besides, necessary for night observations; the lamp being placed before the instrument and above the eye to reflect the light.

When taking the barometer about the screw should be run up full to seal the end of the tube and if to be taken a considerable distance the instrument should be carried in an inverted position.

Hygrodeik.

Swing the index hand to the left of the chart, and adjust the sliding pointer to that degree line upon the chart which corresponds with the degree of temperature shown upon the engraved stem of the Wet Bulb Thermometer. Then swing the index hand to the right, until the sliding pointer intersects the curved line which extends downward to the left from the degree line upon the chart corresponding with the indicated temperature of the Dry Bulb Thermometer. At this intersection the index hand will point to the Relative Humidity on the scale at bottom of chart.

For example: Should the temperature indicated by the Wet Bulb Thermometer be 72° and that of the Dry Bulb 86°, the index hand will indicate Relative Humidity 48% when the pointer rests on the intersecting lines of 72° and 86°.

Observe the intersection as above, and follow the curved line passing through it, which runs from the top downward to the right, to the point of contact with the Dry Bulb scale. The degree (65) at this point on that scale is the Dew Point. The figure at the upper end of this line gives the absolute amount of water in grains (6.8 grains) per cubic foot of air.

One-Tenth Cubic Foot Bottle.

Set the bottle up on the wooden stand as shown in illustration and put in place the two adjustable shelves for the tank. Set the tank on the upper shelf and connect it to the bottom of the bottle by the rubber tube.

Fill the tank with water to within 2 inches of the extreme top. Set the thermometer in the top of the tank so that the bulb is in the water. Open the cock on the bottom of the bottle and at least one cock on the top. Open the cock on the tank, permitting the water to run slowly into the bottle until it rises a little above the index, or marker, on the upper glass tube. Then lower the adjustable shelf on which it stands until by experiment the point is found where the water remains at the exact level of the top of the marker on the upper gauge glass, being at the same level inside the tank.

Then place the tank on the lower shelf, letting the water run from the bottle to the tank. Adjust the shelf so that the water will remain exactly at the level of the top of the marker on the lower glass tube, being at the same level in the tank.

Level the meter and set the waterline with precision as previously explained, having the inlet and outlet open to the air and the temperature of air, water in tank and water in meter the same.

Connect the inlet of the meter by rubber tubing to one of the cocks at the top of the bottle, closing the other cock.

Replace the tank on the upper shelf and let the bottle fill, forcing the contained air through the meter. Repeat this a few times, opening the cock at top of bottle to which the meter is not connected for air supply when placing the tank on bottom shelf.

Bring the large pointer on meter exactly to zero on the dial by turning to right, or note its exact position for a starting point.

Make several runs of the bottle on the meter, noting the reading after each and observing the variation if any from a complete revolution of the large hand in thousandths of a cubic foot.

On taking the average of these runs the percentage of error is expressed by the number of thousandths of a cubic foot by which the reading differs from 100, there being 100 divisions, or thousandths of a cubic foot, in one revolution of the large circle, equal in total to 1/10th of a cubic foot passed from the bottle. For example, if the average shows a reading of 99/1000ths the meter registers 99/1000ths of a cubic foot while passing 100/1000ths and is therefore 1% slow. If it registers 101/1000ths it is 1% fast.